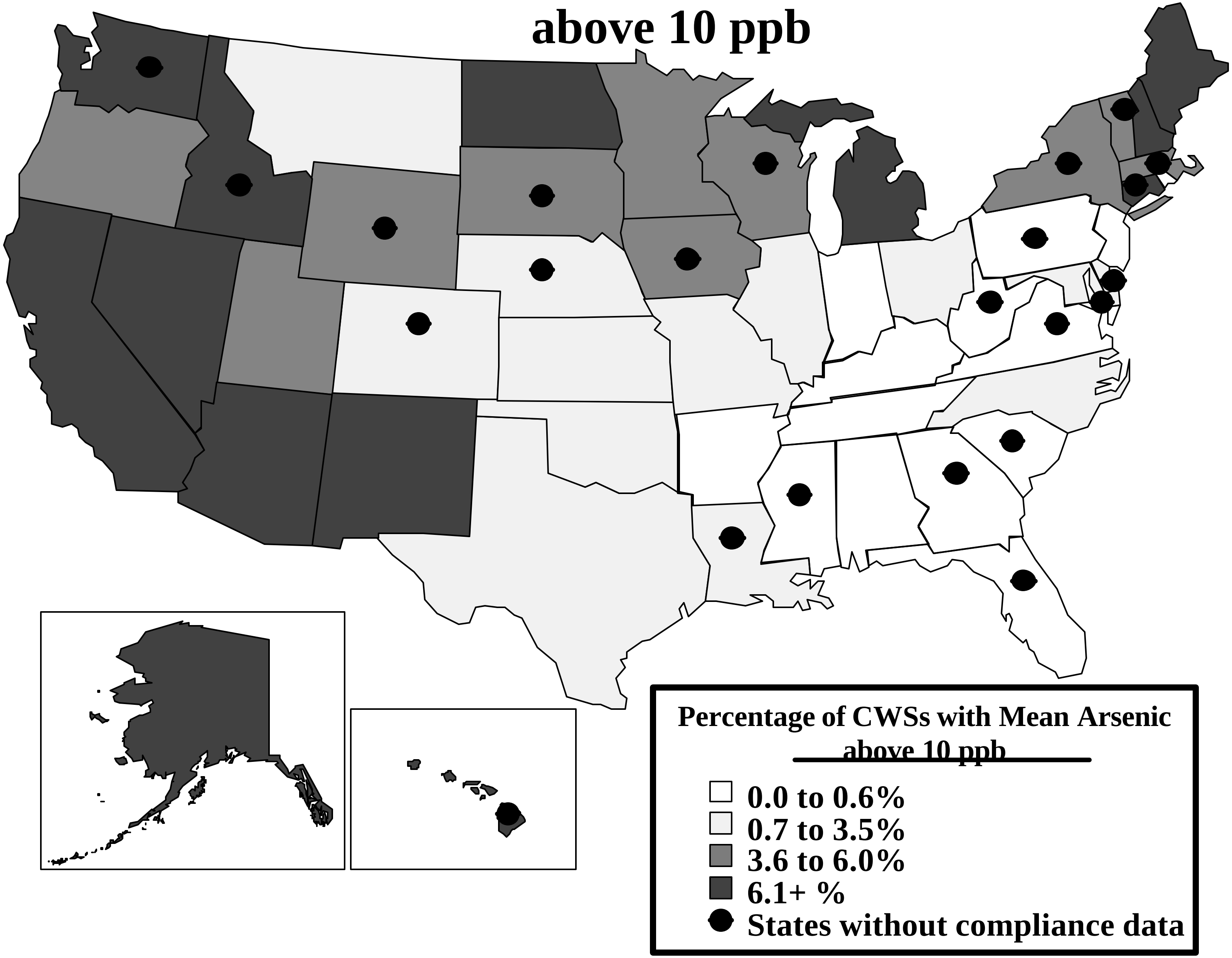
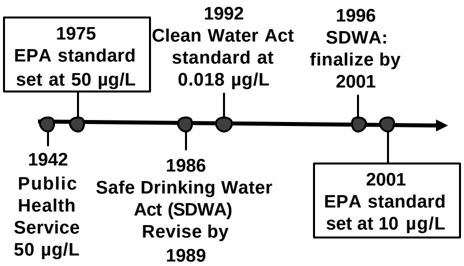
Arsenic Rule

Implementation

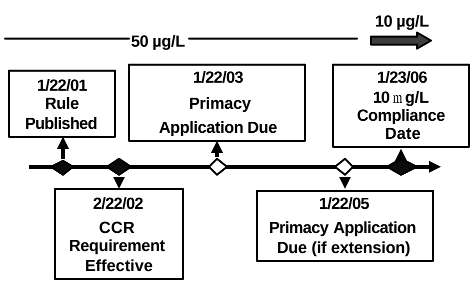
Percentage of CWSs with Mean Arsenic above 10 ppb



Arsenic Regulatory History



Implementation Milestones



Arsenic: Summary of New Rule

- MCL lowered to 10 µg/L
- Applies to CWSs AND NTNCWSs
- Enforceable January 23, 2006

Arsenic: Summary of New Rule

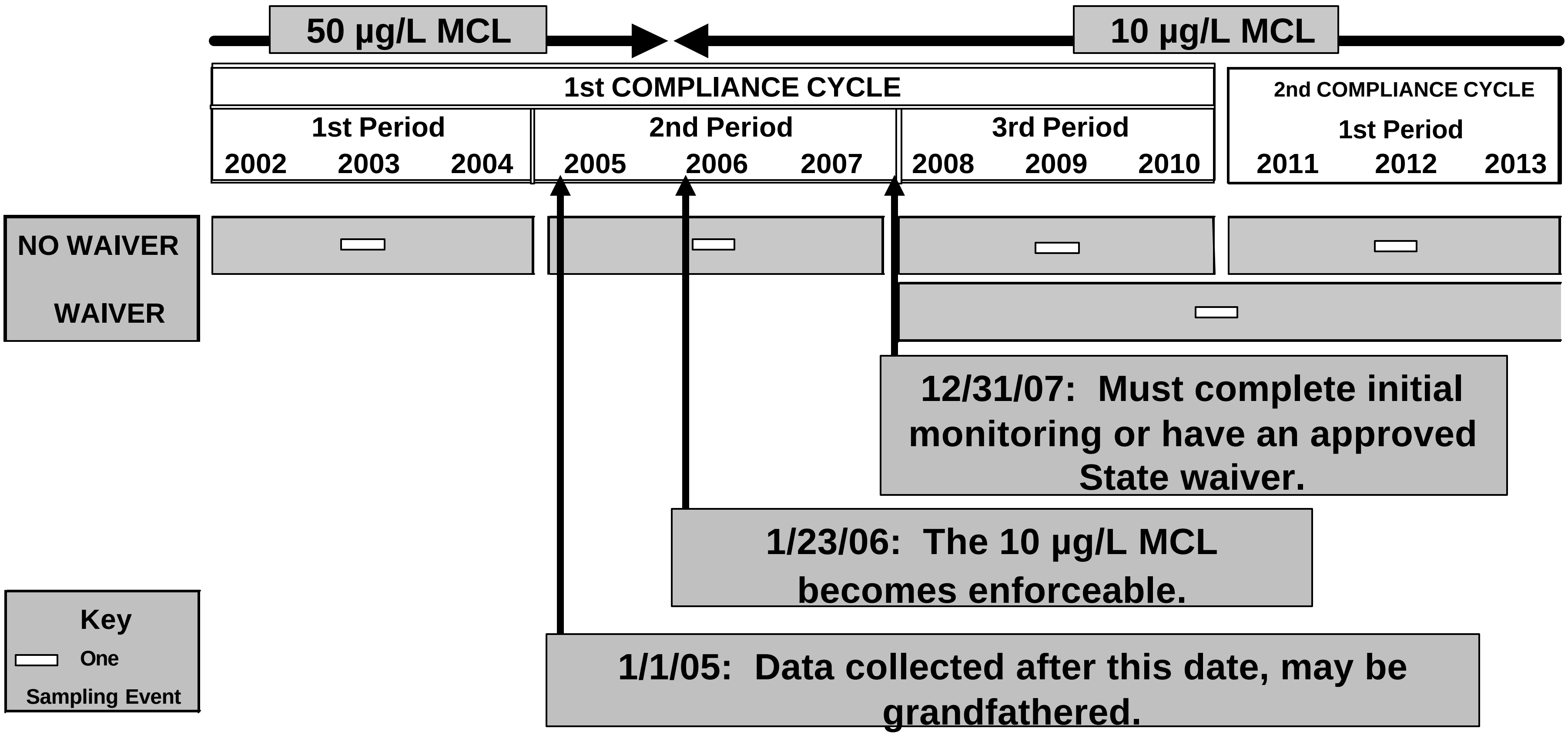
- Arsenic added to Standardized Monitoring Framework
  - No changes to current monitoring practices
- New requirements for Consumer Confidence Reports (CCR)

Arsenic Monitoring

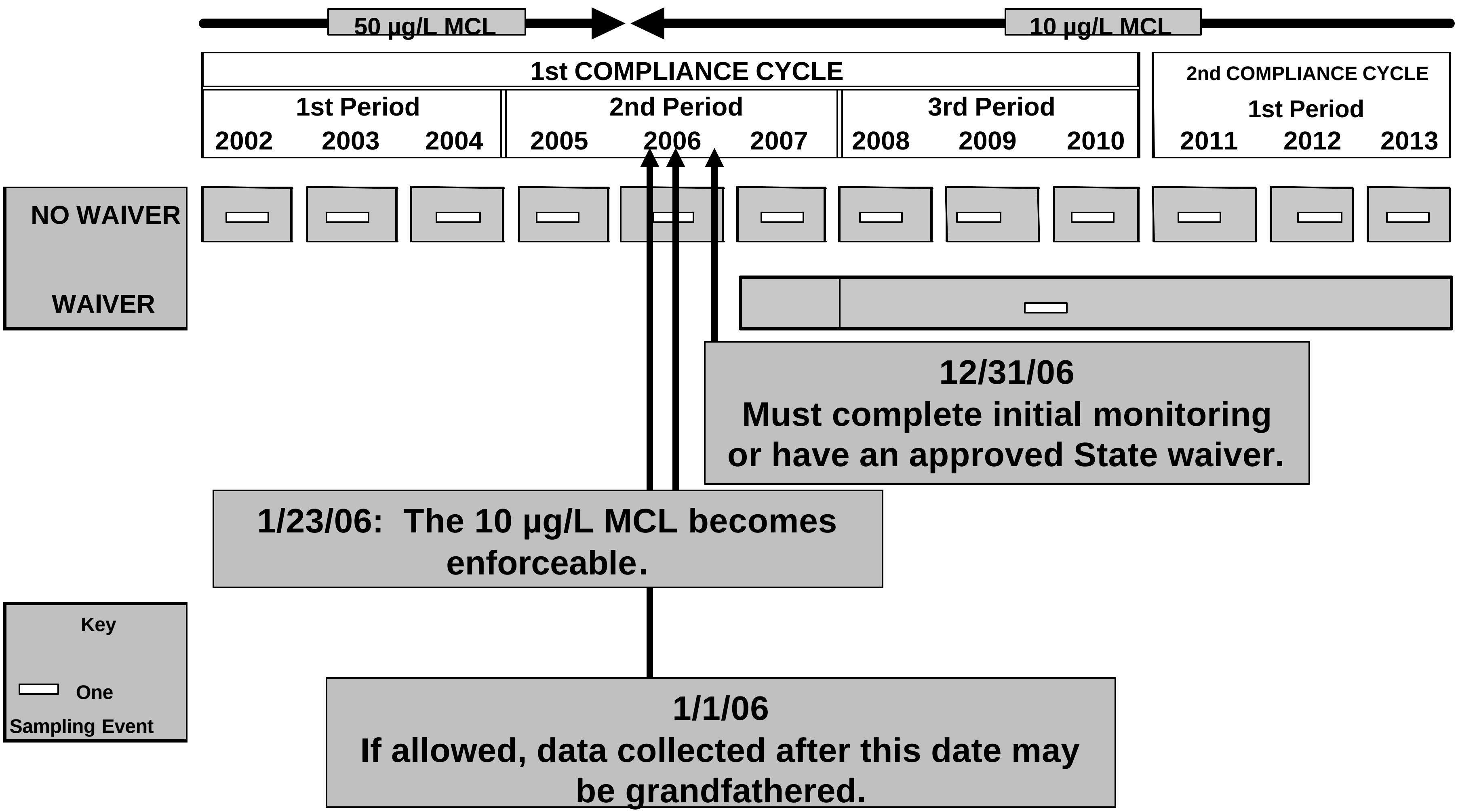
- Placed in Standardized Monitoring Framework
- Systems may continue current monitoring schemes
  - Grandfathered data
  - Extension of monitoring deadline
- Waivers can be granted

This slide left intentionally blank

Standardized Monitoring Framework: Ground Water Systems



Standardized Monitoring Framework: Surface Water Systems



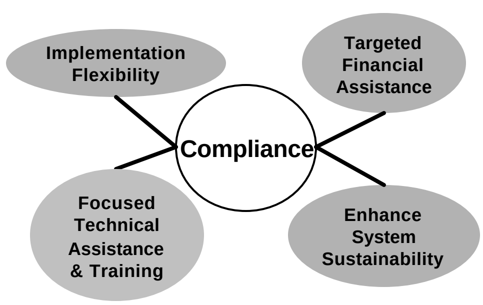
Consumer Confidence Report Requirements

Due Date	Arsenic Detect Level	Informational Statement	Health Effects Statement	Violation Identified
7/1/02 & beyond	> 5 ppb but £ 10 ppb	Ö		
7/1/02 thru 7/1/06	>10 ppb but £ 50 ppb		Ö	
7/1/07 & beyond	> 10 ppb		Ö	Ö

IOC, VOC, & SOC Compliance New Requirements

- For systems monitoring annually or less often
  - MCL exceedance triggers quarterly monitoring
  - Violation determination based on 4 quarters of monitoring
  - Violation if annual average exceeds MCL

EPA's Implementation Strategy



Financing Treatment

- Drinking Water State Revolving Fund
  - Principal mechanism for compliance funding
  - FY'03 budget request - $850 million

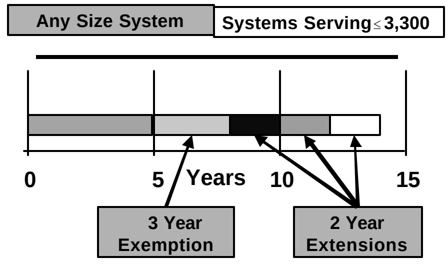
Financing Treatment

- Rural Utilities Service (Dept. of Agriculture)
  - $750 million annually (not all for compliance)
  - Arsenic compliance a funding priority
  - www.usda.gov/rus/water/programs.htm

Exemptions [SDWA 1416(a)]

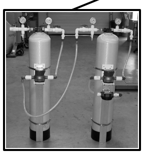
- Useful prioritization tool for states
- Provides additional time for the most disadvantaged systems
  - Up to 9 additional years for small water systems
- Puts system on path to compliance
- EPA guidance streamlines approach

Exemption Time Frames



Implementation Flexibility

Two SDWA Treatment Paths



Centralized Treatment

Point of Use

SDWA Safeguards to Protect Public Health [1412(b)(4)(E)]

- POU prohibited for microbial contaminants
- Units must be owned, maintained, and operated by PWS
- POUs must be equipped with mechanical warnings
- Devices must be independently certified, if product standards exist

Implementation of POU Option To Protect Public Health

- Protective Program will involve:
  - Rigorous maintenance program
  - Consumer participation and education
  - Monitoring strategy
  - Pilot testing

Additional Information

EPA Arsenic website
www.epa.gov/safewater/ars/implement.html

Safe Drinking Water Hotline
(800) 426-4791 or (703) 285-1093
sdwa@epa.gov

Arsenic

Mitigation Strategies

Presentation Summary

- Resources
- Arsenic chemistry
- Monitoring and planning
- Treatment avoidance options
- Treatment options
  - Existing
  - New
- Piloting
- Regulatory considerations
- Decision trees
- Panel discussion

Resources

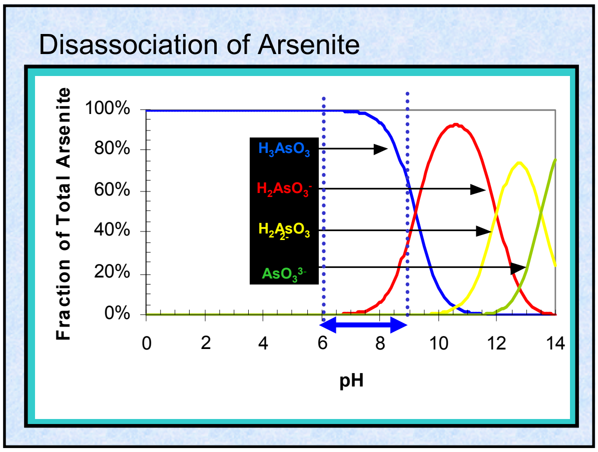
- EPA -- *Arsenic Treatment Technology Evaluation Handbook for Small Systems*
- EPA -- *Design Manual: Removal of Arsenic From Drinking Water Supplies by Adsorptive Media*

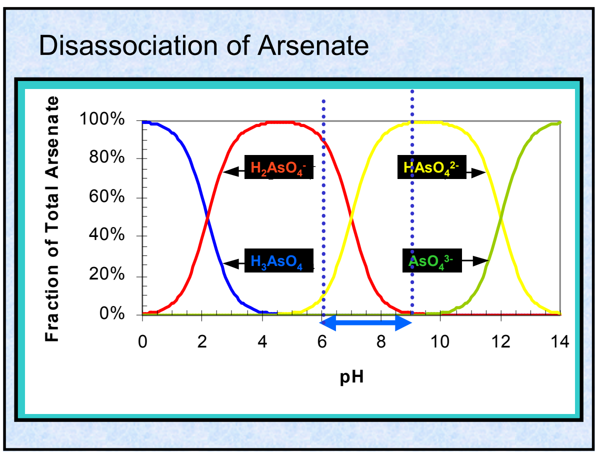
Resources

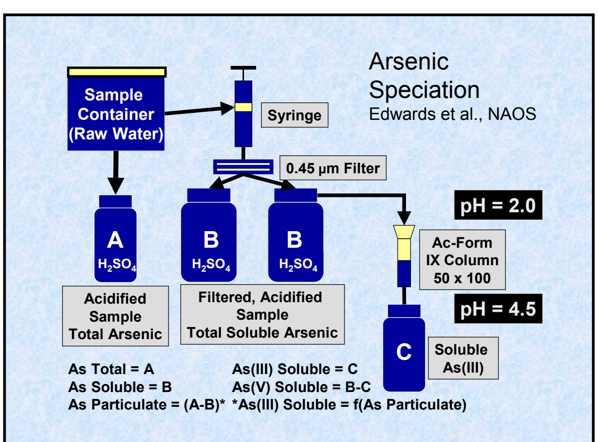
- EPA -- *Design Manual: Removal of Arsenic From Drinking Water Supplies by Ion Exchange*
- AWWARF -- *Implementation of Arsenic Treatment Systems:*
  - *Part 1: Process Selection*
  - *Part 2: Design Considerations, Operation, and Maintenance*

Arsenic Chemistry

- Found in water in two oxidation states
  - Arsenite (trivalent As III)
  - Arsenate (pentavalent As V)


Disassociation of Arsenite
Fraction of Total Arsenite
100%
80%
60%
40%
20%
0%
0
2
4
6
8
10
12
14
pH
H_3AsO_3
$H_2AsO_3^-$
$H_2AsO_3^{2-}$
AsO_3^{3-}


Disassociation of Arsenate
Fraction of Total Arsenate
100%
80%
60%
40%
20%
0%
0
2
4
6
8
10
12
14
pH
$H_2AsO_4^-$
$HAsO_4^{2-}$
H_3AsO_4
AsO_4^{3-}


Arsenic Speciation
Edwards et al., NAOS
Sample Container (Raw Water)
Syringe
0.45 µm Filter
pH = 2.0
Ac-Form IX Column 50 x 100
pH = 4.5
A H_2SO_4
B H_2SO_4
B H_2SO_4
C
Acidified Sample Total Arsenic
Filtered, Acidified Sample Total Soluble Arsenic
Soluble As(III)
As Total = A
As Soluble = B
As Particulate = (A-B)*
As(III) Soluble = C
As(V) Soluble = B-C
*As(III) Soluble = f(As Particulate)

But, For Practical Purposes….

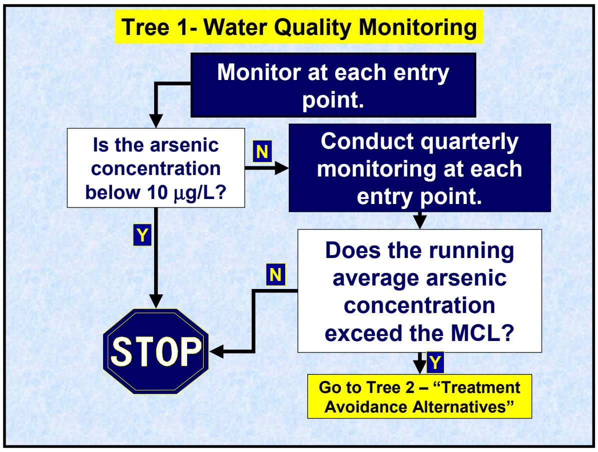
- Plan on oxidation by chlorination
  - All technologies remove arsenic V better than arsenic III
  - Many States will require disinfection
- Some exceptions, however

Mitigation Techniques

- Treatment Avoidance
- Centralized treatment
  - Techniques
    - Side-stream treatment
    - Full treatment
  - Technologies
    - Existing
    - New

Decision Tree Overview

- Step 1: Water quality monitoring
- Step 2: Treatment avoidance
- Step 3: Optimizing existing treatment
- Step 4: Selecting new treatment

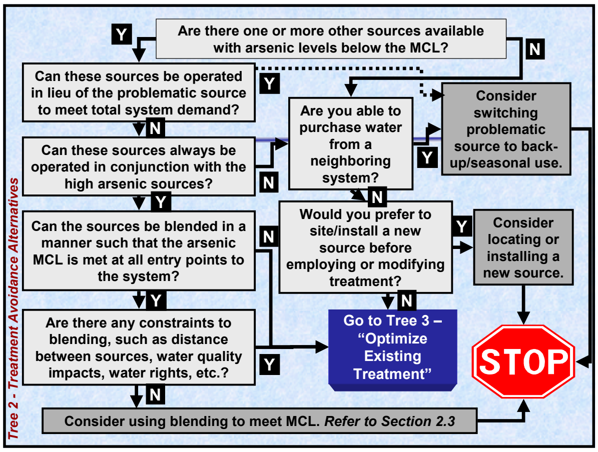


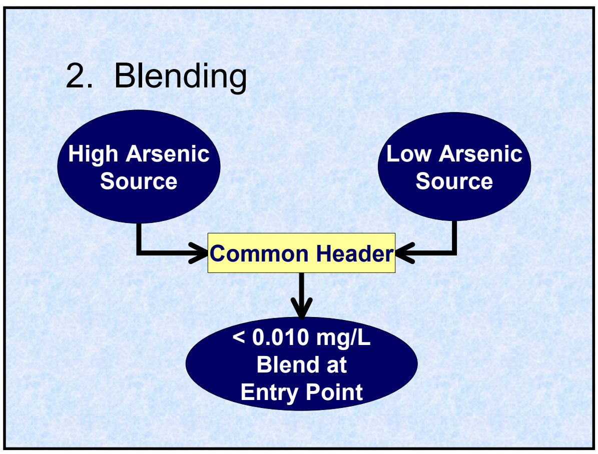
Step 2: Treatment Avoidance Options

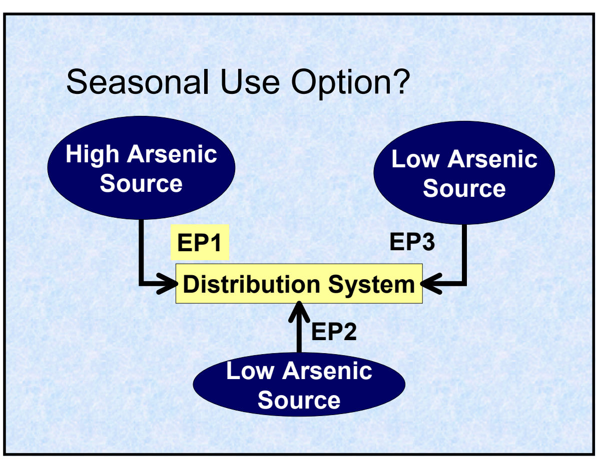
1. Alternative Sources
2. Blending

1. Alternative Source(s)

- Abandon high arsenic source(s)
- Use sources that meet standards


Tree 2 - Treatment Avoidance Alternatives
Are there one or more other sources available with arsenic levels below the MCL?
Can these sources be operated in lieu of the problematic source to meet total system demand?
Can these sources always be operated in conjunction with the high arsenic sources?
Can the sources be blended in a manner such that the arsenic MCL is met at all entry points to the system?
Are there any constraints to blending, such as distance between sources, water quality impacts, water rights, etc.?
Are you able to purchase water from a neighboring system?
Would you prefer to site/install a new source before employing or modifying treatment?
Consider switching problematic source to back-up/seasonal use.
Consider locating or installing a new source.
Go to Tree 3 – "Optimize Existing Treatment"
STOP
Consider using blending to meet MCL. Refer to Section 2.3
Y
N


2. Blending
High Arsenic Source
Low Arsenic Source
Common Header
< 0.010 mg/L Blend at Entry Point


Seasonal Use Option?
High Arsenic Source
Low Arsenic Source
EP1
EP3
Distribution System
EP2
Low Arsenic Source

Treatment Options

Step 3: Optimization of Existing Technologies

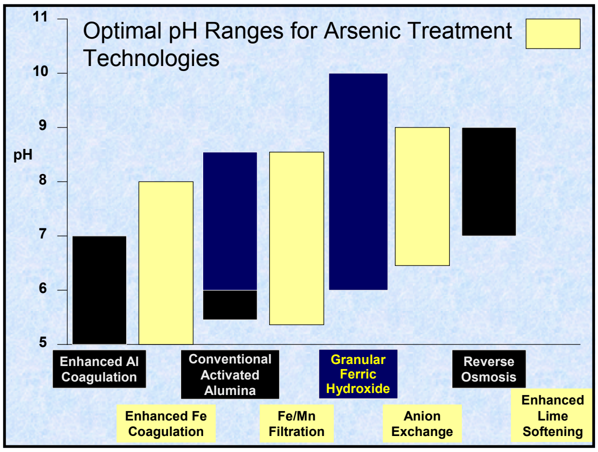
Step 4: Addition of New Technologies

4 Categories of Technologies

- Sorption Processes
  - Ion Exchange (IX)
  - Activated Alumina (AA)
  - Granular Ferric Hydroxide (GFH)
- Iron & Manganese Removal
  - Oxidation & Filtration

4 Categories of Technologies

- Membrane Processes
  - Reverse Osmosis
  - Nanofiltration
- Chemical Precipitation Processes
  - Coagulation Assisted Microfiltration
  - Enhanced Coagulation / Filtration
  - Enhanced Lime Softening



BULLETIN!

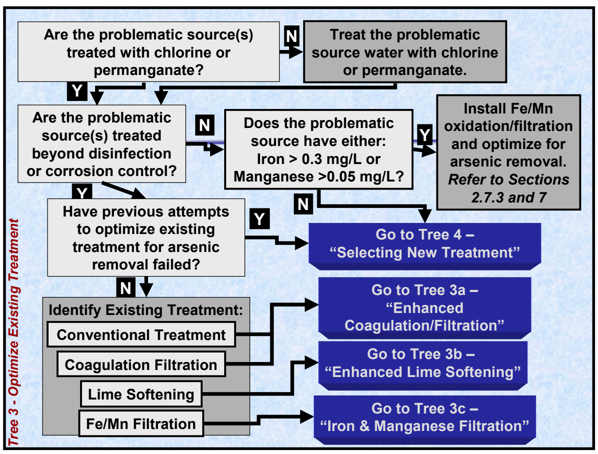
- Throw-away adsorptive technologies
  - Likely to be the treatment of choice for many small systems

Harvard Treatment Plant Video

Film Clip on Harvard

Activated Alumina

Full Scale Operation at a Small Community PWS

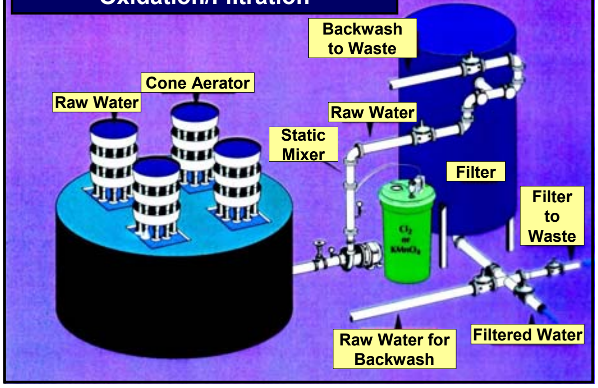


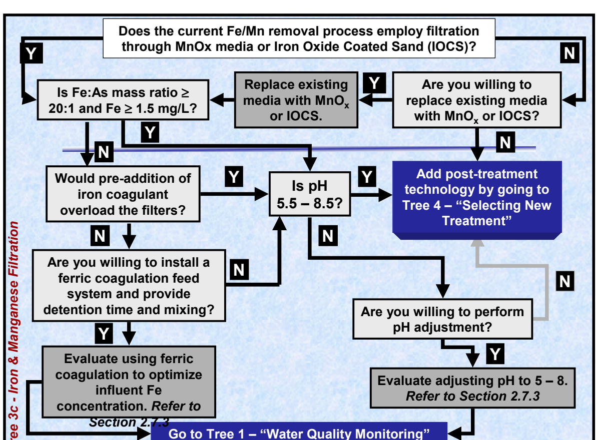
Step 3: Optimization of Existing Technologies

- Iron and Manganese Removal
  - Oxidation/Filtration
- Enhanced Coagulation/Filtration
- Enhanced Lime Softening

Iron and Manganese Removal: Oxidation/Filtration

Iron and Manganese Removal Oxidation/Filtration





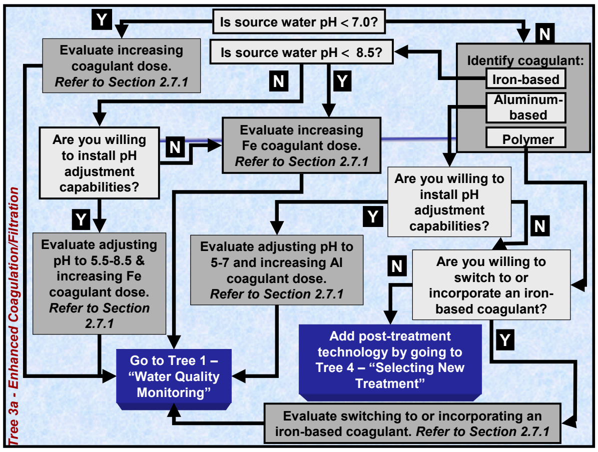
Residuals Produced

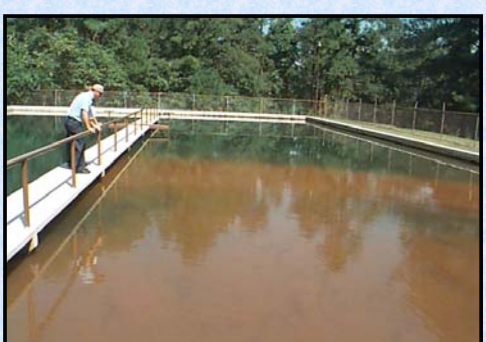
- Liquids
  - Backwash water
  - Supernatant
- Solids
  - Sludge

Enhanced Coagulation/Filtration

Enhanced Coagulation/Filtration

- Defined in Stage 1 D/DBP Rule
- Alum & Ferric Chloride (most common)
  - Metal hydroxide species formed
  - pH range
    - 6 – 7 for Alum
    - 6 – 8 for Ferric Chloride


Tree 3a - Enhanced Coagulation/Filtration
Is source water pH < 7.0?
Y
N
Evaluate increasing coagulant dose. Refer to Section 2.7.1
Is source water pH < 8.5?
Identify coagulant:
Iron-based
Aluminum-based
Polymer
N
Y
Are you willing to install pH adjustment capabilities?
N
Evaluate increasing Fe coagulant dose. Refer to Section 2.7.1
Y
Evaluate adjusting pH to 5.5-8.5 & increasing Fe coagulant dose. Refer to Section 2.7.1
Are you willing to install pH adjustment capabilities?
Y
N
Evaluate adjusting pH to 5-7 and increasing Al coagulant dose. Refer to Section 2.7.1
N
Are you willing to switch to or incorporate an iron-based coagulant?
Add post-treatment technology by going to Tree 4 – "Selecting New Treatment"
Y
Go to Tree 1 – "Water Quality Monitoring"
Evaluate switching to or incorporating an iron-based coagulant. Refer to Section 2.7.1



Residuals Produced

- Liquids
  - Backwash water
  - Supernatant
- Solids
  - Sludge

Enhanced Coagulation/Filtration

- Pros
  - Uses existing technology
  - Can be optimized for arsenic removal
  - Disinfection Byproduct Precursor (DBPP) removal

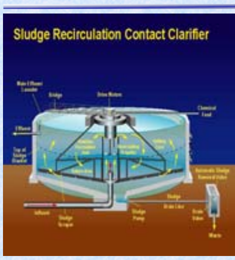
Enhanced Coagulation/Filtration

- Cons
  - Generally only cost effective for existing technology
  - Increased chemical use
  - More sludge
  - Lead/Copper problems

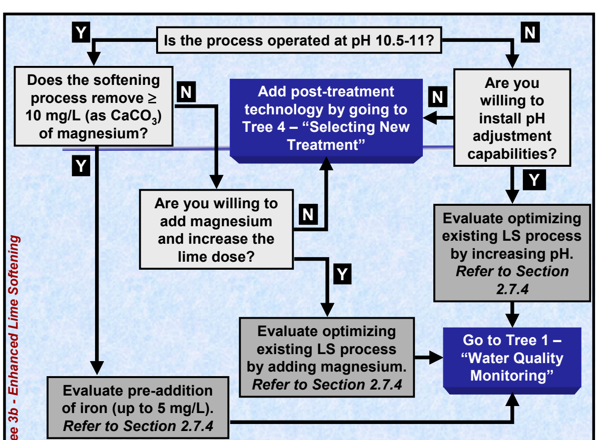
Enhanced Lime Softening

- Pros
  - Uses existing technology
  - Can be optimized for As removal
  - DBPP removal

Enhanced Lime Softening



- Cons
  - Costly for new treatment
  - Chemical use
  - Sludge production



Centralia Video of Mn Removal Plant

Step 4: Installation of New Technologies

Membrane Processes

Sorption Processes

Raw Water Testing: Primary Parameters

- Total arsenic
  - Arsenite
  - Arsenate
- Chloride
- Fluoride
- Iron
- Magnesium
- Manganese
- Nitrate/Nitrite
- Orthophosphate
- pH
- Silica
- Sulfate
- Total Dissolved Solids (TDS)

Raw Water Testing:Secondary Parameters

- Secondary parameters
  - Alkalinity
  - Aluminum
  - Calcium
  - Turbidity
  - Hardness

Design Information

- Capacity of source(s)
- Location of source(s)
- Maximum day water use
  - Gravity storage
- Peak instantaneous demand
  - Hydropneumatic systems

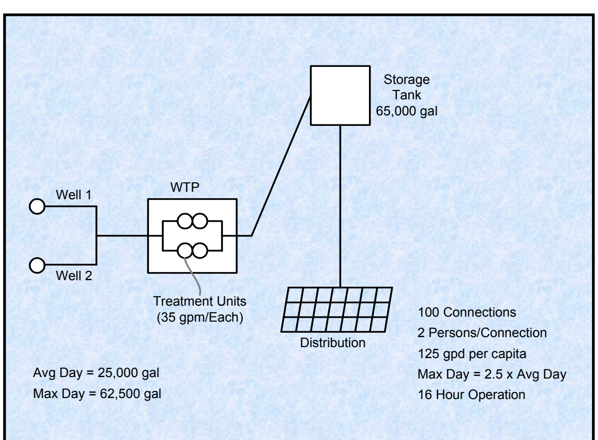
Design Information

- Target finished water arsenic concentration
- Other
  - Publicly Owned Treatment Works (POTW)
  - Land
  - Labor
  - Acceptable water loss

2 Systems With 100 Service Connections

System 1:

- Gravity Storage = Max. Day
- 2 wells with single entry point
- Assume:
  - 125 gpcpd ave.
  - 2 people/connection
  - Max = 2.5 x ave.
  - 16 hour/day pumping
  - 62,500 gpd = max day



System 1:

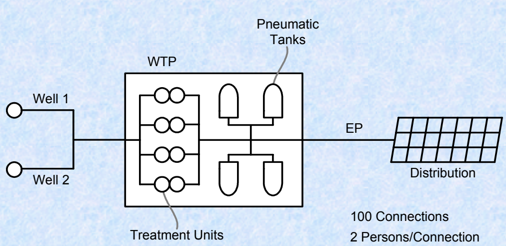
62,500 gpd = 65 gal/min
960 min/day

Figure two trains @ 35 gal/min each

Provides Max Day & Average Day with Largest Treatment Unit Out of Service

System 2:

- Hydropneumatic tanks
- 2 wells with single entry point
- Assume:
  - 125 gpcpd ave.
  - 2 people/connection
  - Max = 2.5 x ave.
  - 16 hour/day pumping
  - 62,500 gpd = max day



Avg Day = 25,000 gal
Max Day = 62,500 gal

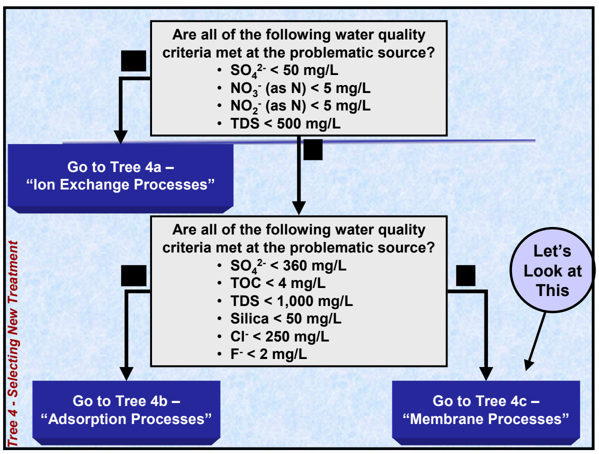
100 Connections
2 Persons/Connection
125 gpd per capita
Max Day = 2.5 x Avg Day
16 Hour Operation

System 2:

Salvato: Probable Max. Momentary Demand = 140 gpm

Figure 4 trains @ 50 gal/min each

Provides Max Momentary Demand with Largest Treatment Unit Out of Service

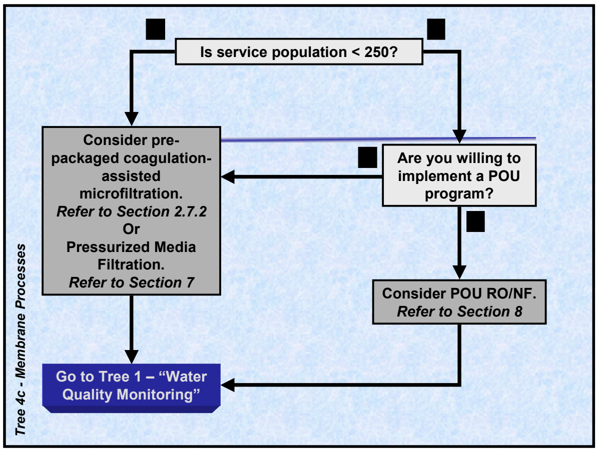


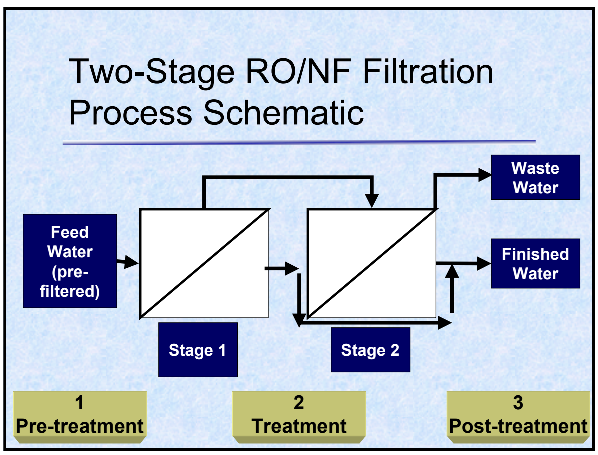
Membrane Processes

Reverse Osmosis*

Nanofiltration

Coagulation Assisted Microfiltration


Is service population < 250?
Consider pre-packaged coagulation-assisted microfiltration.
Refer to Section 2.7.2
Or
Pressurized Media Filtration.
Refer to Section 7
Are you willing to implement a POU program?
Consider POU RO/NF.
Refer to Section 8
Go to Tree 1 – "Water Quality Monitoring"
Tree 4c - Membrane Processes


Two-Stage RO/NF Filtration Process Schematic
Waste Water
Feed Water (pre-filtered)
Finished Water
Stage 1
Stage 2
1 Pre-treatment
2 Treatment
3 Post-treatment

Residuals

- Liquids
  - High total dissolved solids (TDS) in waste water
- Solids
  - Membranes

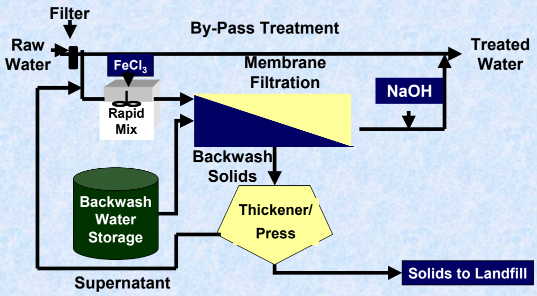
Reverse Osmosis/Nanofiltration

- Pros
  - Effective for arsenic removal
  - Effective for removal of other contaminants
  - Applicable for POU or POE

Reverse Osmosis/Nanofiltration

- Cons
  - Pretreatment often required
  - May require
    - Oxidant
    - pH adjustment
  - Energy requirements
  - Residuals
  - Post treatment
  - Water loss

Coagulation Assisted Membrane Filtration



Coagulation Assisted Membrane Filtration

- Pros
  - Minimal residuals
  - Very little water loss (< 0.1 %)
  - Relatively easy process control
  - Low chemical requirements

Coagulation Assisted Membrane Filtration

- Cons
  - High equipment costs
  - Finished water adjustment may be necessary
    - pH
    - Fluoride

Sorption Treatment Processes

Ion Exchange

Activated Alumina

Granular Ferric Hydroxide

Now, let's look at this

Are all of the following water quality criteria met at the problematic source?

- SO_4^{2-} < 50 mg/L
- NO_3^- (as N) < 5 mg/L
- NO_2^- (as N) < 5 mg/L
- TDS < 500 mg/L

Go to Tree 4a – "Ion Exchange Processes"

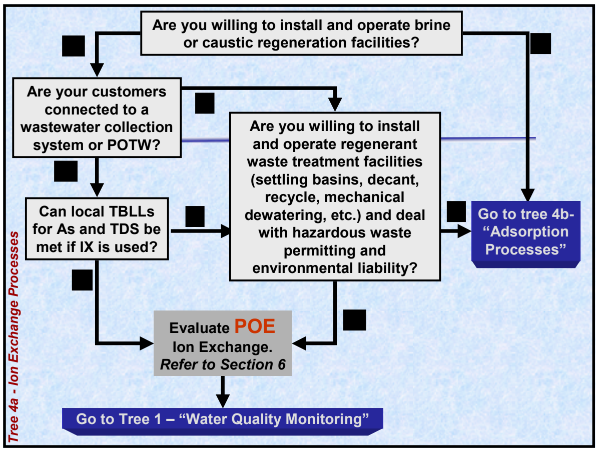
Are all of the following water quality criteria met at the problematic source?

- SO_4^{2-} < 360 mg/L
- TOC < 4 mg/L
- TDS < 1,000 mg/L
- Silica < 50 mg/L
- Cl^- < 250 mg/L
- F^- < 2 mg/L

Go to Tree 4b – "Adsorption Processes"

Go to Tree 4c – "Membrane Processes"

Tree 4 - Selecting New Treatment



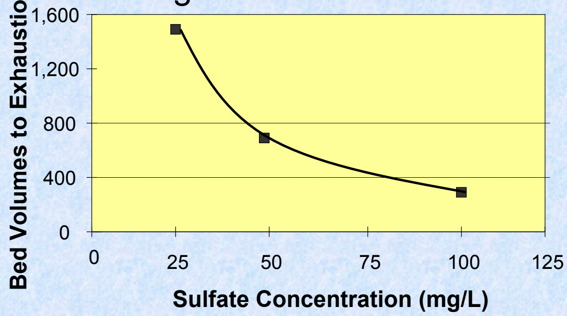
Ion Exchange

- Physical-chemical process
  - Ions exchanged between a solution phase and solid resin phase
  - Strong-base anion exchange resin
  - Insensitive to pH in range of natural waters

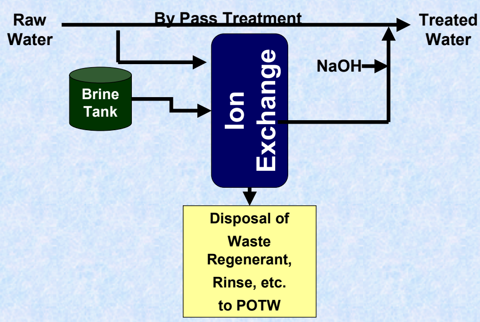
Ion Exchange

- Exchange affinity is a function of net surface charge
- SO42- > HAsO42- > NO3- > NO2- > Cl- >H2AsO4- > Si(OH)4
- High TDS can adversely affect the performance

Effect of Sulfate on Ion Exchange Performance



Ion Exchange Process



Cation Exchange

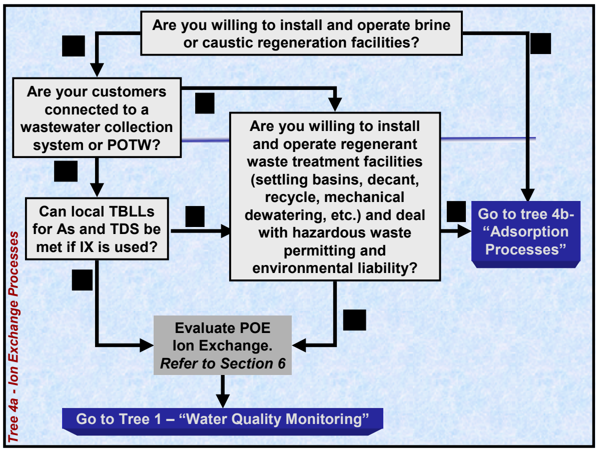
Anion Exchange

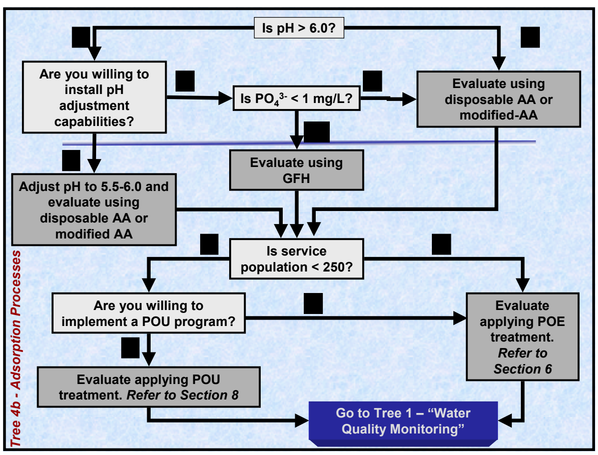
Ion Exchange

- Pros
  - Operates on demand
  - Short contact time (flow insensitive)
  - Insensitive to pH over the range of natural waters
  - Lower chemical requirement (except for NaCl) than for AA or coagulation/microfiltration
  - Appropriate for small systems

Ion Exchange

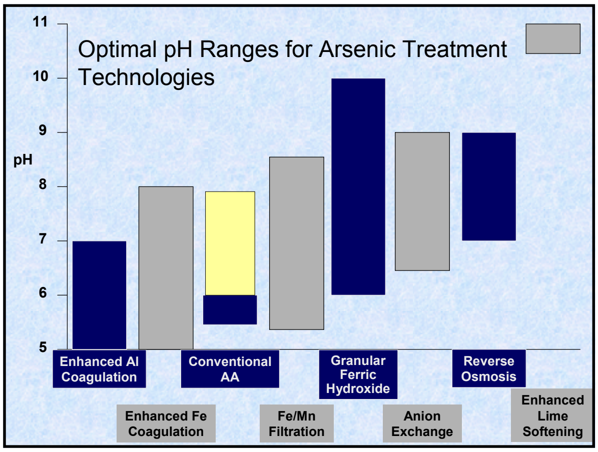
- Cons
  - Large volumes of salt
  - Sulfate can be a problem
  - Finished water pH adjustment may be required
  - Chromatographic peaking
  - Large volumes of brine for disposal





Sorption Processes (Continued)

Activated Alumina*

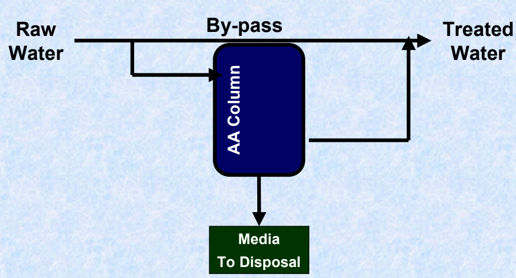


Activated Alumina

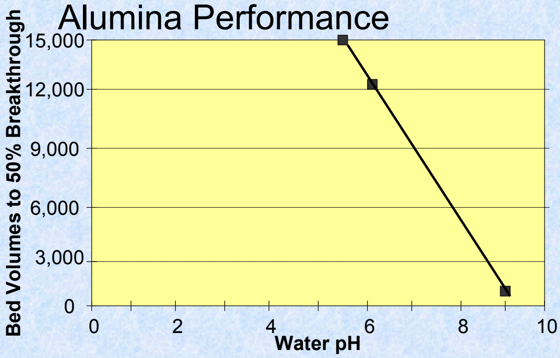
- Porous granular media (aluminum trioxide) with ion exchange properties
- Competing ions

$OH^- > H_2AsO_4^- > Si(OH)_3O^- > F^-$
$> HSeO_3^- > TOC > SO_4^{2-} > H_3AsO_3$

Activated Alumina Process (Throw-Away)



Effect of pH on Activated Alumina Performance



Activated Alumina: Pros

- Operates on demand
- Relatively insensitive to TDS and sulfate
- High quality finished water possible
- Highly selective for arsenic and fluoride
- Disposable media option
- Affordable

Activated Alumina: Cons

- Regeneration
  - Both acid and base required
  - Causes loss of removal efficiency
  - Produces significant volume of spent regenerant
  - Pre- and post-pH adjustment
  - Media tend to dissolve
  - Slow adsorption kinetics
  - Removes fluoride
  - Waste disposal

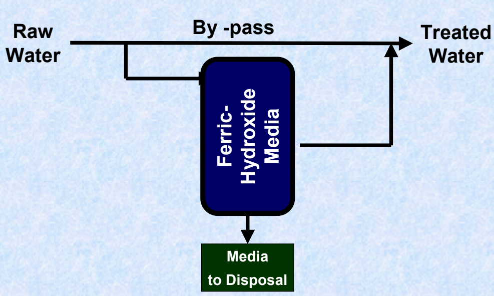
Emerging Disposable Media

- Conventional AA
- Iron-Modified AA
- High Porosity AA
- Proprietary AA
- Granular Ferric Hydroxide

Emerging Disposable Media

- High As removal at natural pH
- Disposable; no regeneration required
- No hazardous wastes produced
- NSF 61 certified

Iron-Based Sorbents



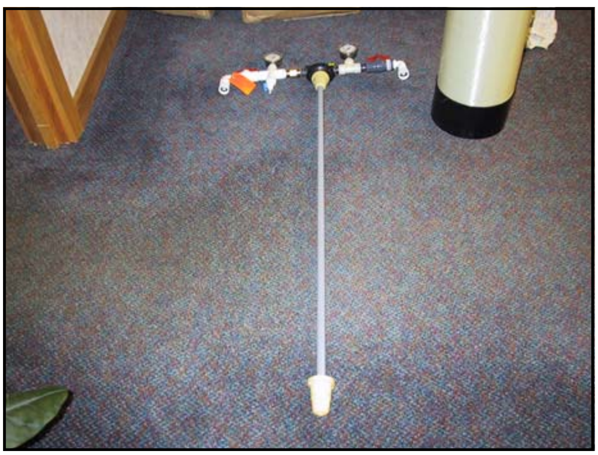
Need For Pilot Testing

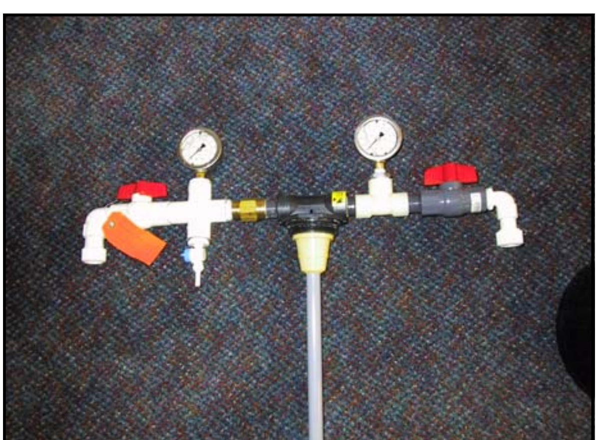
- New media
- Interferences
- Pilot – Small Scale Column

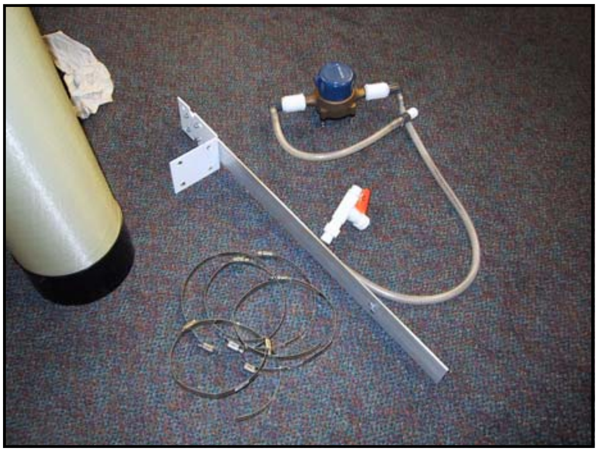
Protocol

- **Objectives**
- **Media Description**
- **Process Description**
- **Project Schedule**
- **Project Documentation**
- **WQ Data Collection and Analysis**
- **QA/QC**
- **Residual Management and Disposal**

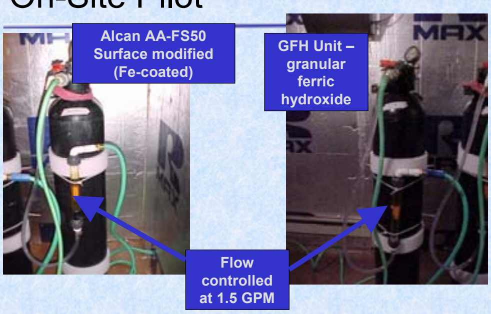
Film Clip on Pilot Plant







On-Site Pilot



Pilot Testing – Scottsdale

Pilot Testing – Scottsdale

- High water temperature caused problems with ion exchange (IX) testing
  - Scaling of control system
- All media become more effective as pH approaches 6.0

Pilot Testing – Scottsdale

- Guard columns needed
  - Unpredictable peaks with pH excursions
- AA > MCL
  - 72,000 bed volumes
- GFH near non-detection
  - > 62,000 bed volumes

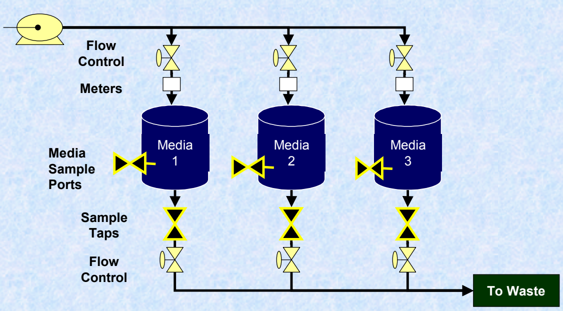
Century Well – Full Scale

- **Head Space?**
  - **Capital cost reduction**
- **4' Diameter X 5' High**
  - **50 gpm currently with 5 minutes EBCT**
    - **(32" of media)**
  - **Up to 90 gpm**
- **$0.5 Million**
  - **(Mn removal, office, storage, etc.)**
- **$10 – 20,000 for a single vessel**

Piloting Potential Technologies

- Arsenic removal
  - Compliance
  - Cost
- Waste production and disposal
  - Compliance
  - Cost

Pilot Plant



Break Followed by:

Residuals Management
(Filmed)

Arsenic

Waste Management

Solids and Liquids

Waste Disposal – Contaminants Impacting Disposal Alternatives

- High or Low pH
- High Total Suspended Solids (TSS)
- High Total Dissolved Solids (TDS)
- High Concentrations of Heavy Metals
- High Concentrations of competing ions
- Fluoride, sulfate, chloride
- Radionuclides and daughter products

Statutes

- The Resource Conservation and Recovery Act (RCRA)
- Clean Water Act (CWA)
  - National Pollutant Discharge Elimination System (NPDES)
- Safe Drinking Water Act (SDWA)
  - Underground Injection Control (UIC)

Solid Residual Disposal

- Solid Phase
  - Spent media
  - Membranes
  - Sludge

Solid Residual Disposal

Liquid Waste Residual

- Liquid Phase
  - Brines
  - Concentrates
  - Backwash
  - Rinse water
  - Filter to waste etc.

RCRA: Determining Waste Characteristics

- A person who generates a solid waste must determine if that waste is a hazardous waste (40 CFR 262.11)
  - Listed wastes
  - Characteristic Wastes
  - Excluded wastes

RCRA Regulatory Tests

- Paint Filter Liquids Test
- Toxicity Characteristic Leaching Procedure (TCLP)

Paint Filter Liquids Test

- Wastes containing free liquids banned from disposal in municipal solid waste landfills and hazardous waste landfills
- Liquid wastes must be treated or disposed in an alternative manner

Paint Filter Liquids Test

- Determines if "free" liquids are present in a waste

Toxicity Characteristic Leaching Procedure (TCLP)

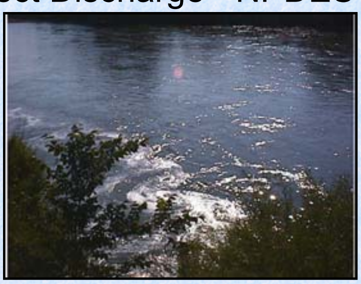
- Predicts if hazardous components of a waste are likely to leach out
- Regulatory levels established for
  - 8 metals
  - 32 organics

Exceeding regulatory levels result in designation as hazardous

TCLP

Non-Hazardous Waste Landfill

Direct Discharge - NPDES



Indirect Discharge - POTW

- Requires permit - talk to POTW or Primacy Agency permitting agency

Indirect Discharge - POTW

- Must not interfere with POTW operations or pass through excessive pollutants to sludge
- Must meet pretreatment requirements / POTW Technically Based Local Limits (TBLLs)
  - Local decision
  - Primacy agency decision

Land Application

- Land Application Clean Sludge Limit (LACSL)
  - As concentration <41 mg/kg – designated clean
  - As concentration >41 mg/kg – limited to 41 kg/hectacre

Disposable Media Options/ Testing Required

- Recycle or Discharge Backwash water
  - Talk to State Permitting Agency regarding requirements
- Landfill spent media
  - Paint Filter Test
  - Toxicity Characteristic Leaching Procedure (TCLP)

Century Well – Full Scale

Case Study #1

TCLP Results of Spent Adsorptive Media

Spent Adsorption Media

Element	AA Media #1 mg/L	AA Media #2 mg/L	AA Media #3 mg/L	Iron – Based Media mg/L	TCLP TC mg/L	Cal WET STLC mg/L
Arsenic	0.0074	<0.01	<0.01	0.011	5.0	5.0
Barium	4.6	3.9	2.6	7.5	100	100

Case Study #1

WET Results of Spent Adsorptive Media

WET Spent Adsorption Media

Element	AA Media #1 mg/kg	AA Media #2 mg/kg	AA Media #3 mg/kg	Iron – Based Media mg/kg	Cal WET STLC mg/L	Cal WET TTLC mg/kg	Cal WET STLC mg/L
Arsenic	30.8	22.9	15.1	413	2.9	500	5
Barium	149	369	330	622	-	10,000	100
Chromium	ND	ND	20.3	31.1	-	500	5

Case Study #2

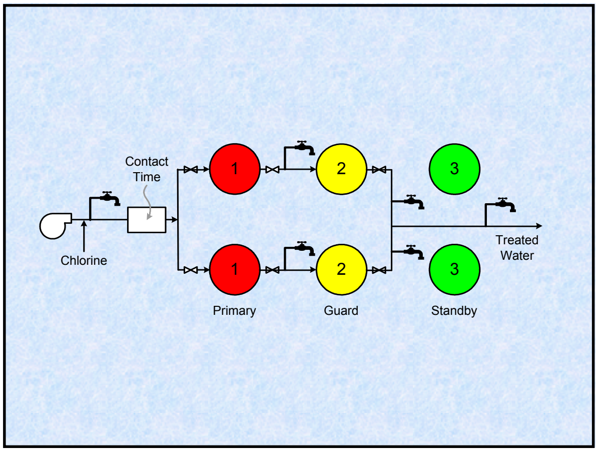
IX Plant Backwash/Regeneration

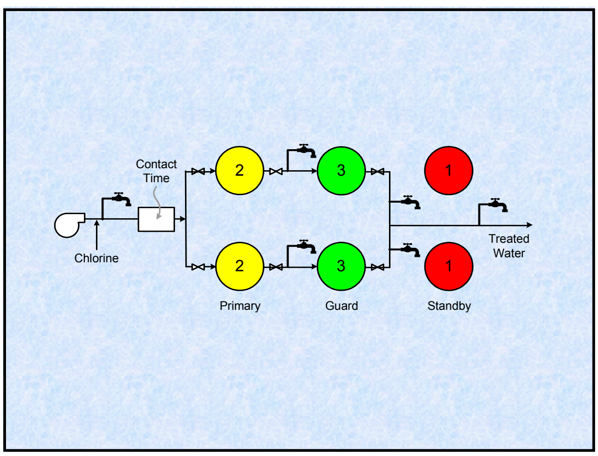
IX Backwash Regeneration

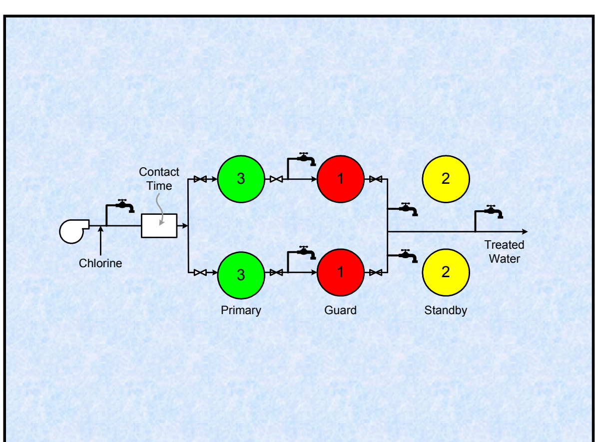
Parameter	Units	# Samples	Min. Conc.	Max. Conc.	Avg. Conc.	Arsenic TC
Backwash:						
TSS	mg/L	5	6.0	24.0	14.0	-
Total As	: g/L	5	28.9	74.4	59.4	5000
Brine Rinse:						
TSS	mg/L	5	6.0	13.0	9.0	-
Total As	: g/L	5	1,830	*38,522*	*15,623*	5000
Slow Rinse:						
TSS	mg/L	5	0.5	22.0	9.6	-
Total As	: g/L	5	253	3,060	1,332	5000
Fast Rinse:						
TSS	mg/L	5	0.5	4.0	1.2	-
Total As	: g/L	5	6.9	356	108	5000

Century Well Video

Review and Summary


Contact Time
Chlorine
1
2
3
1
2
3
Treated Water
Primary
Guard
Standby


Contact Time
Chlorine
2
3
1
2
3
1
Treated Water
Primary
Guard
Standby


Contact Time
Chlorine
3
1
2
3
1
2
Treated Water
Primary
Guard
Standby

Regulatory Design Considerations

- Configuration
  - Parallel
  - Series
  - By-pass
  - Pre-treatment
  - Post-treatment
- Redundancy
- Loading rates
- Process control monitoring

Presentation Summary

- Resources
- Arsenic chemistry
- Monitoring and planning
- Treatment avoidance options
- Treatment options
  - Existing
  - New
- Piloting
- Regulatory considerations
- Residuals management
- Panel discussion

Implementation In Arizona

Jeff Stuck